PHOSPHORUS FERTILIZATION OF SHAMOUTI ORANGE GROVES[1])

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The response of citrus groves to phosphorus fertilization has been the subject of extensive and careful investigation in many citrus-growing countries. No definite conclusions, however, have been reached. For many years fertilizer experiments and surveys in Californian citrus groves had failed to prove any beneficial effect of phosphorus fertilization on the quantity and quality of yields. In 1949, however, *Aldrich* and *Haas* (1) found phosphorus deficiency in lemon groves. In 1951, *Chapman* and *Fullmer* (7), in a survey of the nutritional status of citrus groves by means of leaf analyses, reached the conclusion that 11 % of the groves examined suffered from a moderate phosphorus deficiency, while 10 % of the groves had an excess of this element.

In Israel, *Naim* (16) reported an increase in orange yields after superphosphate applications, whereas in long-term fertilizer trials in Mique Israel (4) yield increase due to phosphorus was slight and largely confined to the first years of the experiments, whilst commercial fruit quality was not much affected.

On the other hand, it is generally agreed that phosphorus applications produce citrus fruit with thinner peel and juice of lower acidity. Since the fruit produced in the first yields following heavy pruning of orange trees is inordinately large and coarse (18), the question arose whether the quality of these yields may be improved by phosphorus applications. Fertilizer trials were therefore established in two severely pruned orange groves. A third grove with exceptionally coarse fruit was also included in the experiment.

EXPERIMENTAL PROCEDURE

The Zirkin and Eisenberg groves as well as the layout of the pruning and fertilizing experiments conducted in these groves had been described by *Oppenheimer* (18). For the phosphorus trials, each of the existing experimental plots was divided into two subplots, one of which was annually supplied with 2 kg of superphosphate per tree, while the other served as control. Establishment of guard rows between the subplots reduced the number of experimental trees, compared with Oppenheimer's experiments.

The experimental scheme in the Gottesmann grove has been described elsewhere (11). It included different combinations of the annual superphosphate dose per tree and method of application: 1/2 kg spread broadcast and covered shallowly by hoeing (considered as control). 2) 1 kg applied at a depth of 20 cms by means of a soil auger, in 6 holes around each tree. 3) 1 kg applied in aqueous solution with the irrigation water, according to the recommendations of *Ravikovitch* and *Lachover* (21). 4) 2 kg introduced into holes (12 holes around each tree). 5) 2 kg in solution.

1) Abridged translation from Hebrew.

2. *Fruit size*

The smaller orange sizes (180 and smaller) are preferred in Israel both for the local market and for export. Generally speaking, larger crops consist of smaller fruit, and vice versa.

No direct effect of superphosphate applications on fruit size was observed in the Zirkin and Eisenberg groves. It is, however, noteworthy, that there was no increase in fruit size, although the yields were much reduced by the applications.

In the Gottesmann grove, fertilization with superphosphate in solution at the rate of 2 kg per tree increased the percentage of small fruits in the 1945/46 crop. This may be explained by the increase in total yield due to this treatment. In the follwing seasons smaller fruit was borne on trees of the superphosphate-treated plots, compared with the controls (table 4, p. 87).

In this grove superphosphate increased the proportion of small oranges in total yields by about 15%, but other factors were responsible for a more substantial rise in the amount of small fruit. In the control, the percentage of small fruit rose from 31.8% to 79.1% of total yields. This reduction in fruit size is probably due to the general increase in yields, promoted by nitrogen fertilization and clean cultivation, during the experimental period.

Although the compiled data for the three groves indicate a certain trend towards reduced fruit sizes due to phosphorus fertilization, it seems that the supply of phosphorus is not the most important factor determining fruit size.

3. *Fruit grade*

Generally speaking, more than 50% of total yields belonged to fancy grade, and with the exception of the Eisenberg grove, the proportion of culls did not exceed 10%.

In the *Zirkin grove* the effect of phosphorus on fruit grade was not statistically significant (table 5, p. 88). There was, however, a pronounced trend towards a larger percentage of fancy fruit in the plots fertilized with phosphorus as compared with the controls. Since the trials were superimposed on plots which had received differential nitrogen fertilization, it is worth noting that heavy nitrogen application resulted in a marked deterioration of fruit quality.

In the *Eisenberg grove* superphosphate did not affect the proportion of fancy grade fruit in total yields, but it produced a commercially negligible, though statistically significant, increase in the percentage of culls (table 6, p. 88). This effect may be due to the thinner rind of fruit from the superphosphate-treated plots.

In the *Gottesmann grove* fruit quality was improved in the first two seasons (1944/46) following application of 2 kg of superphosphate per tree (table 7, page 89). In 1946/47, however, this heavy phosphorus application considerably decreased the proportion of fancy grade fruit. Leaf analyses showed an excess of phosphorus in the trees concerned (11). The deterioration of fruit quality probably resulted from a relative deficiency of other essential elements. In 1947, 1/2 kg of superphosphate was applied to all the experimental trees. In the 1947/48 crop, differences in quality of fruit between treatments were less pronounced, but nevertheless fruit quality was still inferior in the plots previously supplied with 2 kg of superphosphate per tree, while it was excellent in plots which had had moderate phosphorus fertilization.

These data suggest that moderate phosphorus applications improve fruit quality, whereas an excess of phosphorus affects it adversely.

The criteria used for sizing and grading of fruit were the same as in Oppenheimer's experiments (18).

RESULTS

The following results should be considered as preliminary, since the experiments were carried out in commercial groves and were continued for 3—4 years only.

1. *Yields*

Zirkin grove. Superphosphate was applied in February 1945. In the two following seasons, the yields of the fertilized plots were significantly lower than those of the controls, although in the 1945/46 season the reduction was mainly confined to the nitrogen deficient plots (Table 1, p. 84)[1]).

Analyses of leaves from these experimental plots (11) support the conclusion that phosphorus applications induced an antagonistic depression of nitrogen absorption. Since nitrogen constituted the nutritionally limiting factor, the reduction of yields due to phosphorus application must be considered as a secondary effect.

Eisenberg grove. Superphosphate was applied in July-August 1945. The grove consisted of recently rejuvenated tress; thus the yields in the 1945/46 season were relatively small and were not affected by the phosphorus application (table 2, p. 85). The marked increase in yields of the following season implies a relative scarceness of nitrogen supply to the trees. This may explain the serious reduction of yields due to superphosphate application, which amounted to an average of one field box per tree. Leaf analyses supported the assumption that nitrogen absorption by trees was reduced as a result of phosphorus application. This antagonistic relationship would also explain the slower regeneration of the severely pruned trees which was observed in the phosphorus fertilized plots.

Gottesmann grove. The excessively large and rough-skinned fruit yielded by this grove was indicative of phosporus deficiency. Although the grove had not been fertilized for several years and its cultivation had been neglected, the trees were vigorous and produced high yields. In January 1945, superphosphate was applied. At the same time normal nitrogenous fertilization and culivation were resumed. These treatments resulted in a steady rise in yields during the following seasons.

In this grove, the large differences in response between individual trees and the small number of replications (four) were responsible for a high experimental error. In 1945/46—the first season following phosphorus application—a significant increase in yields was recorded for the plots which had received 2 kg of superphosphate per tree, particularly where the fertilizer was applied in solution (table 3, p. 86). Leaf analyses showed this to be the only treatment which increased the phosphorus content in leaves (11). We may conclude that phosphorus intake by the trees was facilitated by heavy applications of superphosphate given in solution. In the following seasons the various treatments had no significant effect on yields, other than an exceptionally high yield in 1946/47 of trees supplied with 1 kg of superphosphate in solution.

These results suggest the following explanation. A moderate phosphorus deficiency had developed in the Gottesmann grove, due to the lack of fertilization in combination with high yields. Therefore, effective absorption of phosphorus readily produced an increase in yields. In the subsequent seasons, the superphosphate, supplied more moderately in the other treatments, became increasingly available, thus providing enough phosphorus for all the trees.

1) Page numbers in parentheses refer to the Hebrew text.

4. *Fruit composition*

The composition of fruit from the Zirkin grove was examined during two seasons. The data in table 8 (page 89) are averages for eight plots which had received different pruning and nitrogenous fertilization treatments. Each plot was represented by a sample consisting of 40 fruits picked from two trees. It may be seen from the table that superphosphate applications resulted in fruit with thinner peel and considerably reduced juice acidity. There was no consistent effect of phosphorus upon other examined fruit constituents.

DISCUSSION

In Israel as well as in other citrus-growing countries, superphosphate is generally supplied to orange groves, though evidence of any beneficial effects is lacking. In the light of our findings, the advisability of such liberal use of phosphorus fertilizers is questioned. Similar conclusions have been reached recently by several Californian authors, who found that phosphorus applications may increase the need for nitrogen in citrus groves (6) or may result in an actual reduction of yields (20). Corresponding results have been obtained with deciduous fruit trees (3, 4, 15, 23) and with pineapple (17).

Citrus growers should carefully consider whether superphosphate applications are advisable in their groves. This fertilization may have desirable effects on yields as well as on fruit quality in a grove affected by a relative phosphorus deficiency. On the other hand, under conditions of low nitrogen supply, phosphorus may reduce yields. Particular caution in the use of superphosphate should be exercised in neglected groves and in groves situated on sandy soils, especially when there are grounds for suspecting inadequacy of nitrogen supply.